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Function and Complications After Ablative and Limb-Salvage Therapy in Lower Extremity Sarcoma of Bone

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Background and Objectives: The functional results and the complications after several limb-saving and ablative treatments because of lower extremity bone sarcoma were evaluated.

Methods: Seventy-seven surviving patients were evaluated according to the MSTS (American Musculoskeletal Tumor Society) functional rating system. Fifty-two patients had limb-saving and 25 had ablative therapy. Median follow-up was 97 months in the limb-saving group and 112 months in the ablative group.

Results: Functional results in the limb-saving group were significantly better than in the ablative group ($P = 0.0001$). Functional results in patients with tumors about the knee joint were significantly better ($P = 0.0064$) after limb-saving surgery (i.e., endoprosthesis, knee arthrodesis, or rotationplasty) compared to functional results after ablative surgery (i.e., hip or knee disarticulation or above-the-knee amputation). Complications were 3 times more common after limb-salvage procedures and 4 times more common after endoprosthetic reconstructions compared to after ablative procedures. Complications after limb-saving therapy were fewest in tumors about the knee joint. In 3/28 patients, the endoprosthetic reconstruction had to be converted to an amputation.

Conclusions: Functional results were significantly better after limb-saving compared to after ablative therapy. Complications, however, were more common after limb-saving therapy.

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KEY WORDS: **comparative study; lower extremity bone sarcoma; limb-salvage therapy; ablative therapy; functional results; complications**

INTRODUCTION

A few decades ago the aim of treatment of extremity sarcoma was to save the patient's life. Since chemotherapeutic agents, sophisticated radiotherapy, better surgical techniques, and new imaging techniques have improved survival rates dramatically, the quality of the saved life must be taken into consideration [1]. Several limb-saving procedures have been developed in the last 2 decades to achieve this goal [1]. The functional outcome and quality of life after different surgical modalities in musculoskeletal tumor treatment is being assessed in many centers worldwide.

In this report, a comparison is made between the functional outcome and complications after ablative and limb-saving therapy in 77 patients with lower extremity

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chondrosarcoma (CS), Ewing sarcoma (ES), or osteosarcoma (OS) of bone.

MATERIALS AND METHODS

One hundred and five patients with lower extremity CS, ES, or OS of bone were treated from 1975 to July 1995 at the Nijmegen University Hospital. Of these 105 patients, 39 had CS, of whom 10 had ablative surgery [4 died of disease (DOD)], 28 had limb-saving surgery (0 DOD), and 1 did not have surgery (1 DOD). Forty-six patients had OS, of whom 29 had ablative surgery (15 DOD), 14 had limb-saving surgery (7 DOD), and 3 did not undergo surgery (3 DOD). Twenty patients had ES, of whom 8 had ablative surgery (4 DOD), 7 had limb-saving surgery (1 DOD), and 5 did not undergo surgery (3 DOD). Thus, 67 patients were alive at the time of follow-up. Ten other patients (3 CS and 7 OS) who had been treated in the Groningen University Hospital were followed up in our hospital and included in this study. Of the total 77 surviving patients, 50 had limb-saving surgery, 25 had ablative surgery, and 2 did not have surgery (Tables I, II).

All patients with ES received chemotherapy and radiotherapy, and patients with OS, except those with parosteal OS, received chemotherapy according to the protocol in effect at the time of diagnosis. Most of the patients with ES were described in an earlier report [4].

At the end of 1997, the 77 surviving patients were evaluated at the outpatient clinic and scored according to the System for Functional Evaluation of the American Musculoskeletal Tumor Society (MSTS) [2]. The functional data of the patients who had a limb-saving procedure were compared with those of the patients with an ablative procedure, using nonparametric statistics by a Kruskal-Wallis 1-way analysis of variance (ANOVA). The α level of significance was 0.05.

There were 42 male and 35 female patients. The age of the patients at diagnosis varied from 2 to 70 years, with a median of 30 years. The median age was 33 years in the limb-saving group and 24 years in the ablative group.

In 10 of the 25 patients in the ablative group, amputation was performed because of complications following limb-saving procedures.

The median follow-up in the limb-saving group was 97 (28–271) months. The median follow-up in this group after the last oncological operation was 80 (28–271) months. The median follow-up in the ablative group was 112 (42–267) months. In the latter group, the median follow-up after the ablative operation was 61 (2–267) months.

Five patients had coexistent disease influencing functional performance: rheumatoid arthritis (patient 26), arthrogryposis multiplex congenita (patient 24), morbus Ollier (patient 58), and painful polyneuropathy (patients 10 and 25).

Treatment and Functional Results

Details of treatment and functional results are shown in Tables I and II for the limb-saving and ablative groups, respectively.

Proximal Femoral Tumors With Hip Joint Involvement and Pelvic Tumors

Four patients with a sacroiliac joint resection or an Enneking type I or III pelvic resection, with intact pelvic ring, had excellent functional results (median 95%) [5,6].

Three Enneking type IIA (+ III) pelvic resections, with reconstruction with a saddle prosthesis ($n = 2$) or an iliofemoral arthrodesis ($n = 1$), gave good functional results (median 73%). One patient with an Enneking type IIA pelvic resection and total femoral resection, with reconstruction with a saddle prosthesis and total femoral endoprosthesis, had poor functional results (37%).

One external hemipelvectomy gave fair functional results (57%).

Proximal Femoral Tumors

Two patients with a reconstruction with a total femoral endoprosthesis had poor functional results (mean 39%). Six reconstructions with a proximal femoral endoprosthesis gave fair to good functional results (median 70%).

One patient with a hip disarticulation had fair functional results (67%).

Distal Femoral and Proximal Tibial Tumors

Thirteen patients with a reconstruction with a distal femoral endoprosthesis had fair to good functional results (median 70%). One total femoral endoprosthesis gave fair functional results (57%).

Five patients had an arthrodesis of the knee joint, which gave fair to good functional results (median 77%). Two patients with a rotationplasty had a mean functional score of 74%.

Four patients with a hip disarticulation had fair functional results (median 62%). Fourteen above-the-knee amputees had poor to good functional results (median 60%). Three patients with a knee disarticulation also had poor to good functional results (median 77%).

Complications

Limb-saving group.

Early postoperative complications. In 7 patients, a peroneal palsy occurred unintentionally: in 4 it was persistent (patients 17, 33, 47, and 59), in 2 it was transient, and 1 patient still had weakness 5 months after the operation (patient 60).

Two patients had wound margin necrosis leading to amputation (patients 59 and 65). In 3 other patients, a deep infection occurred, leading to amputation in 2 cases (patients 56 and 72). Two superficial infections were

TABLE I. Details of Diagnosis, Treatment, and Outcome in 52 Patients with Limb-Saving Therapy for a Lower Extremity Bone Sarcoma

Case	Sex, age (years)	Type, stage[a]	Site	Surgical therapy	Surgical margin[b]	Follow-up (months)[c]	Outcome[d]	MSTS function (%)[e]
1	M, 47	CS, IB	Pubic bone	Enneking type III resection, partial resection adductors, hamstrings, and obturator nerve	i	28	AWD	90
2	M, 39	CS, IIB	Sacroiliac joint	En bloc resection sacroiliac joint	m	74	NED	100
3	M, 17	CS, IA	Pubic bone	En bloc resection	i	11		
				En bloc resection, resection left ductus deferens and vasa vasorum	m	172	NED	93
4	M, 28	CS, IB	Iliac bone	En bloc resection, intercalary graft, K-wires, allogenic bone	w	108	NED	97
5	M, 41	CS, IIB	Pubic bone	En bloc resection, arthrodesis, K-wires	m	135	NED	73
6	F, 18	CS, IB	Iliac bone	Curettage, cryosurgery, allogenic bone	m	30	NED	93
7	F, 53	CS, IB	Ischial bone	En bloc resection	i	35		
				En bloc resection	i	114		
				Internal hemipelvectomy, saddle prosthesis	i	29	AWD	73
8	M, 16	OS, IIB	Proximal femur	Internal hemipelvectomy, resection proximal femur, saddle prosthesis	m	88	NED	77
9	M, 2	ES, IIB	Proximal femur	Local radiotherapy, 65 Gy	—	271	NED	60
10	F, 64	CS, IA	Proximal femur	En bloc resection, proximal femoral endoprosthesis	w	45	NED	57
11	M, 67	CS, IIA	Proximal femur	En bloc resection, proximal femoral endoprosthesis	w	49	NED	93
12	M, 14	ES, IIB	Proximal femur	En bloc resection, proximal femoral endoprosthesis (femoral revision after 48 months, total revision after 61 months because of aseptic loosening)	w	108	NED	63
13	M, 41	ES, IIB	Proximal femur	En bloc resection, proximal femoral endoprosthesis	w	152	NED	67
14	F, 20	ES, IIB	Proximal femur	En bloc resection, proximal femoral endoprosthesis (cup revision after 66 and 78 months because of recurrent dislocations, femoral revision after 104 months because of aseptic loosening)	w	143	NED	73
15	F, 14	OS, IIB	Proximal femur	En bloc resection, resection extensors and femoral nerve, proximal femoral endoprosthesis (total revision after 185 months because of prosthetic fracture and cup protrusion)	w	188	NED	80
16	F, 66	CS, IIB	Proximal femur	En bloc resection, total femoral endoprosthesis	m	60	NED	37
17	M, 59	CS, IIB	Proximal femur	En bloc resection, total femoral endoprosthesis (exchange acetabular cup after 6 months because of recurrent dislocations)	w	177	NED	40
18	M, 56	CS, IB	Proximal femur	En bloc resection, unipolar prosthesis	i	80		
				Internal hemipelvectomy, femoral resection, saddle and total femoral endoprosthesis	w	47	NED	37
19	F, 26	CS, IA	Distal femur	Curettage, cryosurgery, intramedullary nail	m	38	NED	100
20	F, 41	CS, IA	Distal femur	Curettage, cryosurgery, autogenous bone, plate fixation	m	39	NED	100
21	F, 35	CS, IA	Distal femur	Curettage, cryosurgery, allogenic bone	m	35	NED	90
22	F, 56	CS, IA	Distal femur	Curettage, cryosurgery, allogenic bone	m	33	NED	100
23	M, 36	CS, IA	Distal femur	En bloc resection, distal femoral endoprosthesis	w	65	NED	67
24	F, 45	CS, IA	Distal femur	En bloc resection, distal femoral endoprosthesis	w	59	NED	73
25	M, 45	CS, IA	Distal femur	En bloc resection, distal femoral endoprosthesis	w	68	NED	83
26	F, 64	CS, IA	Distal femur	En bloc resection, distal femoral endoprosthesis	w	102	NED	33
27	M, 56	CS, IA	Distal femur	En bloc resection, distal femoral endoprosthesis	w	47	NED	70
28	F, 41	CS, IIA	Distal femur	En bloc resection, distal femoral endoprosthesis (exchange modular axial rotating hinge knee system after 18 months)	w	187	NED	63
29	M, 44	CS, IIA	Distal femur	En bloc resection, distal femoral endoprosthesis	w	50	NED	83

TABLE I. continued

Case	Sex, age (years)	Type, stage[a]	Site	Surgical therapy	Surgical margin[b]	Follow-up (months)[c]	Outcome[d]	MSTS function (%)[e]
30	M, 14	OS, IIB	Distal femur	En bloc resection, distal femoral endoprosthesis (exchange polyethylene connecting device and total revision after 126 months because of unstable knee joint due to polyethylene wear)	w	193	NED	83
31	M, 15	OS, IIB	Distal femur	En bloc resection, distal femoral endoprosthesis (total revision after 142 months because of prosthetic fracture)	w	201	NED	53
32	F, 30	OS, IIB	Distal femur	En bloc resection, distal femoral endoprosthesis	w	70	NED	70
33	M, 34	OS, IIB	Distal femur	En bloc resection, distal femoral endoprosthesis	m	68	NED	93
34	M, 10	OS, IIIB	Distal femur	En bloc resection, distal femoral endoprosthesis (exchange polyethylene connecting device after 76 months)	w	196	NED	87
35	M, 12	OS, IIB	Distal femur	En bloc resection, distal femoral endoprosthesis (exchange modular axial rotating hinge knee system after 23 months because of dislocation)	w	187	NED	57
36	M, 28	CS, IIB	Distal femur	En bloc resection, knee arthrodesis (intramedullary rod, autogenous bone)	w	193	NED	87
37	M, 19	OS, IIB	Distal femur	En bloc resection, knee arthrodesis (cemented arthrodesis pin)	m	69	NED	73
38	M, 30	OS, IA	Distal femur	En bloc resection, knee arthrodesis (intramedullary rod, autogenous and allogenic bone)	w	196	NED	77
39	F, 5	OS, IIB	Distal femur	En bloc resection, rotationplasty, plate fixation	w	111	NED	60
40	F, 8	OS, IIB	Distal femur	En bloc resection, rotationplasty, plate fixation	w	95	NED	87
41	F, 18	OS, IIB	Distal femur	En bloc resection, total femoral endoprosthesis (exchange acetabular cup after 67 months and exchange total prosthesis after 91 months, both because of aseptic loosening)	w	218	NED	57
42	M, 42	CS, IA	Proximal tibia	Curettage, cryosurgery, autogenous bone, plate fixation	m	39	NED	100
43	F, 31	CS, IA	Proximal tibia	En bloc resection, ipsilateral fibula transposition, autogenous bone, plate fixation (after 25 months, pseudarthrosis repair)	w	41	NED	53
44	M, 41	CS, IA	Proximal tibia	En bloc resection, free vascularized fibula, external fixator	w	98	NED	80
45	F, 29	ES, IIB	Proximal tibia	En bloc resection, knee arthrodesis (cemented arthrodesis pin)	w	33	NED	67
46	M, 18	OS, IIB	Proximal tibia	En bloc resection, knee arthrodesis (cemented arthrodesis pin)	w	45	NED	80
47	M, 11	ES, IIB	Proximal fibula	En bloc resection	i	167	NED	83
48	F, 43	CS, IA	Proximal fibula	En bloc resection, reinsertion lateral collateral ligament	w	36	NED	87
49	M, 14	ES, IIB	Fibular shaft	En bloc resection	w	121	NED	90
50	F, 5	ES, IIB	Distal tibia	Local radiotherapy, 46 Gy	—	159	NED	70
51	F, 45	CS, IA	Distal tibia	Curettage, cryosurgery, autogenous bone	m	40	NED	100
52	M, 53	CS, IB	Talonavicular joint	En bloc resection, talonavicular joint arthrodesis (autogenous bone)	w	153	NED	50

[a]Tumor stage according to Enneking et al. [3]. CS, chondrosarcoma; OS, osteosarcoma; ES, Ewing sarcoma.
[b]i, intralesional; m, marginal; w, wide; r, radical.
[c]Follow-up after the last oncological operation or interoperative interval in case of recurrence.
[d]NED, no evidence of disease; AWD, alive with disease.
[e]MSTS functional evaluation [2].

TABLE II. Details of Diagnosis, Treatment, and Outcome in 25 Patients with Ablative Surgery for a Lower Extremity Bone Sarcoma

Case	Sex, age (years)	Type, stage[a]	Site	Surgical therapy	Surgical margin[b]	Follow-up (months)[c]	Out-come[d]	MSTS function (%)[e]
53	M, 31	CS, IIB	Pelvis	Internal hemipelvectomy, pelvic prosthesis, proximal femoral prosthesis	w	96		
				Exchange femoral component because of aseptic loosening	—	61		
				Total revision with saddle prosthesis because of aseptic loosening	—	22		
				External hemipelvectomy because of septic loosening	—	33	NED	57
54	F, 2	ES, IIB	Proximal femur	Local radiotherapy, 50.8 Gy	—	12		
				Hip disarticulation because of local recurrence	r	161	NED	67
55	M, 27	OS, IIB	Ischiatic spine	Exploration (lumbosacral plexus close to tumor, histology benign)	—	23		
				En bloc resection, histology: osteoblastoma with osteosarcomatous transformation	i	7		
				Internal hemipelvectomy, saddle prosthesis, chemotherapy	i	31		
				Palliative hip disarticulation because of recurrent aggressive osteoblastoma with high-grade osteosarcomatous transformation	i	2	AWD	23
56	M, 56	CS, IA	Femoral diaphysis	En bloc resection, intercalary allograft, intramedullary nail, allogenic bone chips	w	5		
				Above-knee amputation because of persistent infection	—	55	NED	33
57	F, 70	CS, IA	Distal femur	Above-knee amputation	w	53	NED	20
58	M, 44	CS, IIB	Distal femur + proximal tibia	Above-knee amputation (Ollier's disease, patient refused operation for 8 years)	w	45	NED	43
59	F, 35	OS, IIB	Proximal tibia	En bloc resection, distal femoral endoprosthesis	w	1		
				Above-knee amputation because of wound margin necrosis	—	131	NED	67
60	M, 13	OS, IIB	Distal femur	Above-knee amputation	w	45		
				En bloc resection, knee arthrodesis on the other side because of second primary OS	w	5	NED	23
61	F, 13	OS, IIB	Distal femur	Above-knee amputation	w	164	NED	57
62	M, 10	OS, IIB	Distal femur	Above-knee amputation	w	56	NED	67
63	F, 13	OS, IIB	Distal femur	Above-knee amputation	w	107	NED	73
64	F, 49	OS, IB	Distal femur	Above-knee amputation	w	116	NED	23
65	M, 5	ES, IIB	Distal femur	Rotationplasty	w	2 days		
				Above-knee amputation because of necrosis	—	159	NED	73
66	M, 26	ES, IIB	Distal femur	Local radiotherapy, 61 Gy	—	89		
				Above-knee amputation because of local recurrence and infectious pseudarthrosis	w	55	NED	50
67	F, 13	OS, IIB	Distal femur	Hip disarticulation	r	153	NED	60
68	F, 24	OS, IIB	Distal femur	Hip disarticulation	r	267	NED	50
69	M, 10	OS, IIIB	Distal femur	Hip disarticulation	r	237	NED	67
70	M, 5	OS, IIB	Distal femur	Hip disarticulation	r	197	NED	63
71	F, 63	CS, IIB	Proximal tibia	Above-knee amputation	w	42	NED	77
72	F, 50	CS, IA	Proximal tibia	En bloc resection, contralateral fibula transposition, blade plate, autogenous bone	w	50		
				Knee disarticulation because of persistent infection	—	140	NED	83
73	F, 17	OS, IIIB	Proximal tibia	Above-knee amputation	w	61	NED	67
74	M, 8	OS, IIB	Proximal tibia	Above-knee amputation	w	61	NED	63
75	F, 7	ES, IIB	Proximal fibula	Local radiotherapy, 50 Gy	—	179		
				Knee disarticulation because of leg-length discrepancy, peroneal palsy, and pes equinus	—	226	NED	77
76	M, 45	CS, IA	Distal tibia	Curettage	i	2		
				En bloc resection	i	1		
				En bloc resection	i	1		
				Below-knee amputation	w	68	NED	60
77	F, 34	OS, IIB	Distal fibula	Below-knee amputation	w	1		
				Knee disarticulation because of persistent infection	—	51	NED	33

[a]CS, chondrosarcoma; ES, Ewing sarcoma; OS, osteosarcoma.
[b]i, intralesional; m, marginal; w, wide; r, radical.
[c]Follow-up after the last oncological operation or interoperative interval.
[d]NED, no evidence of disease; AWD, alive with disease.
[e]MSTS functional evaluation [2].

successfully treated with debridement and gentamycin beads.

Two pulmonary embolisms occurred and were treated without further sequelae.

Late postoperative complications. Three pseudarthroses developed: once after an intercalary autogenous graft, once after a talonavicular joint arthrodesis, and once after an iliofemoral arthrodesis.

One patient (patient 14) had recurrent dislocations of the femoral component due to insufficient abductor strength; the gluteus musculature was partly resected because of an improperly positioned biopsy tract. A hamstring transfer and 2 cup revisions were performed to overcome the dislocations. A cup revision was performed in another patient because of dislocations.

Seven aseptic endoprosthetic loosenings, necessitating revision, occurred, twice in 3 patients. One septic loosening of a saddle prosthesis occurred following 2 previous revisions, leading to an external hemipelvectomy.

There were 2 prosthetic stem fractures, once of a proximal and once of a distal femoral endoprosthesis; both were revised.

In 2 patients, the axially rotating hinge knee system and, in 2 patients, the polyethylene connecting device of a distal femoral endoprosthesis had to be revised. In 1 patient, a total revision of a distal femoral endoprosthesis was performed because of recurrent knee dislocations.

Six patients sustained fractures: a fracture of the fibula transposition in a case of tibial CS 19 months postoperatively (patient 43), a pathological fracture due to a local recurrence (patient 66), a fracture through the site of curettage and cryosurgery in a case of distal femoral CS 1 month postoperatively, and a periprosthetic fracture in a case of distal femoral endoprosthesis. One patient had 6 osteoporotic fractures of the involved extremity following radiotherapy and immobilization.

Five patients experienced limb-length inequality following radiotherapy for ES, varying from 2 to 24 cm (patients 9,47,49,50, and 75). All had muscular atrophy of the involved leg, and 1 had recurrent osteoporotic fractures. One of these patients underwent a knee disarticulation 15 years after treatment (patient 75) because of the inequality and peroneal palsy with its evolving deformations.

Oncological complications. In 7 patients, an intralesional resection of the primary tumor was performed. In 1 of these patients, the diagnosis was made after femoral head replacement because of a pathological fracture. Two of these patients (patients 55 and 76) underwent ablative surgery because of a local recurrence.

In 2 patients, both treated with local radiotherapy because of ES, a local recurrence occurred (patients 54 and 66) necessitating amputation.

Two patients had pulmonary metastases, both OS. Both underwent a metastasectomy.

Ablative group.

Postoperative complications. One patient (patient 77) had wound margin necrosis and subsequent osteomyelitis following a below-the-knee amputation. Subsequently, a knee disarticulation was performed.

Oncological complications. Two patients had a secondary OS or skeletal metastasis (patients 60 and 64), located in the proximal humerus and the contralateral proximal tibia. They were treated with a proximal humeral resection with reconstruction with an endoprosthesis and a resection arthrodesis of the knee joint, respectively.

Four patients had pulmonary metastases; 1 had CS and the others OS. All underwent a metastasectomy.

DISCUSSION

Functional evaluations and quality-of-life assessments are performed in patients treated because of extremity sarcoma in many centers worldwide. Although intuitively one should think that patients with limb-saving procedures have better function and quality of life, no clear differences in outcome have been found in several studies using the available quality-of-life assessment systems [7–9]. One study reported better functional but equal psychological outcomes after limb-saving compared to ablative surgery in distal femoral osteosarcoma [10]. Other studies also reported no significant difference in psychological outcome [11]. Better functional results after limb-saving surgery using the MSTS functional evaluation system have been reported in several studies [12,13]. The efficiency of gait expressed as net oxygen cost was lower after endoprosthetic replacement compared to after above-the-knee amputation and after rotationplasty compared to after resection arthrodesis or above-the-knee amputation in patients with tumors about the knee joint [14,15]. Others did not find these differences in efficiency comparing the different surgical modalities [8]. Recently, a significant negative correlation between the net energy cost and the overall functional score (MSTS) in patients with endoprosthetic replacement of distal femoral tumors was reported [16].

In our study, the functional results in the limb-saving group were significantly ($P = 0.0001$) better than in the ablative group. The functional results in the limb-saving group varied from 37% to 100%, with a median of 77%. The results in the subgroup of 25 patients with endoprosthetic reconstruction varied from 33% to 93%, with a median of 70%. The results in the group with ablative surgery varied from 20% to 83%, with a median of 60%. Compared to the literature, one study reported an average function after limb-saving and ablative therapy of 64% and 62%, respectively [17].

In our series, excellent results were obtained in pelvic tumors after Enneking types I and III pelvic resections with intact pelvic ring, which is in accordance with data

in the literature [18,19]. Reconstructions after Enneking type IIA resections in periacetabular tumors or proximal femoral tumors with joint involvement resulted in a better functional outcome than external hemipelvectomy (mean 74% vs. 57%). One study reported an average function of 70% after pelvic endoprostheses [20]. Most authors agree that limb-saving therapy is functionally preferable in pelvic tumors [6,18,19]. When limb salvage is not possible in large tumors, external hemipelvectomy must be considered, although one should be aware of the high morbidity and poor prognosis in high-grade pelvic sarcomas [21]. In 1 of our patients, a reconstruction with a saddle prosthesis and total femoral endoprosthesis gave a functional result of 37%; therefore, it is questionable if such a huge reconstruction is preferable to an external hemipelvectomy.

In our study, total femoral endoprostheses gave a mean functional result of 45%. Proximal femoral endoprostheses resulted in better function than hip disarticulation (mean 72% vs. 61%). In the literature, good or excellent function according to the MSTS rating system after proximal femoral endoprostheses was obtained in 48% to 73% of patients [22,23]. One study reported an average functional result of 53% after hip disarticulation [10].

In our series, functional results in patients with tumors about the knee joint were significantly ($P = 0.0064$) better after limb-saving surgery compared to after ablative surgery. Distal femoral endoprostheses had equal function compared to knee arthrodeses (mean 70% vs. 77%) and rotationplasties (mean 70% vs. 74%) but better function than above-the-knee amputations (mean 70% vs. 53%) and knee disarticulations (mean 70% vs. 64%).

According to the literature, good or excellent functional outcome after distal femoral endoprostheses was obtained in 63% to 91% of patients [13,24,25]. Two studies reported an average function of 77% and 80%, respectively [10,26]. In 1 study, functional outcome after rotationplasty was between 50% and 75% in 7/7 patients [12]. One study reported an average function of 63% after above-the-knee amputations [10].

Local radiotherapy for ES in toddlers resulted, in our series, in a mean functional outcome of 62%. One patient had a knee disarticulation after cessation of growth because of limb-length inequality and deformity. Amputation might be indicated in young children with ES in whom gross limb-length inequality is expected [27].

The best functional results in our study were obtained after curettage, cryosurgery with or without bone grafting, and internal fixation in CS stage IA tumors (mean 98%) [28].

In our series, 52 nononcological and 5 oncological complications were encountered in 35/62 patients after limb-saving therapy, leading to 17 endoprosthetic revisions and 10 amputations. Complications were fewest in tumors located about the knee joint. A total of 30 complications occurred in 23/28 patients with endoprosthetic reconstruction, leading to 17 revisions and 3 amputations. Recently, we reported results with endoprosthetic revisions: 24 revisions had been performed in 14 patients with a malignancy of the lower extremity. Two patients ultimately had an amputation; in 2 of the other patients, function deteriorated after the last revision compared to after the primary operation, in 2 function improved, and in 8 function remained the same [29].

In 7/25 patients with ablative surgery, 1 nononcological and 6 oncological complications occurred. One study reported complications in 80/131 patients after limb-saving therapy and in 0/13 patients after amputation [12].

In conclusion, in our series, significantly better functional results were found after limb-saving compared to ablative procedures. No differences were found in function after endoprosthetic reconstructions, arthrodeses, and rotationplasties in tumors located about the knee joint; but these procedures gave significantly better functional results compared to ablative procedures. Complications, however, were encountered more frequently after endoprosthetic reconstruction.

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